DOCUMENT RESUME

ED 172 762 IR 007 383

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TITLE Cost-Effective Computer Management of Instruction.
PUB DATE Apr 79
NOTE 14p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, California, April 1979) ; Best copy available

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Computer Managed Instruction; *Cost Effectiveness; Educational Equipment; Educational Facilities; *Educational Finance; *Educational Testing; *Education Service Centers; Higher Education; Personnel
IDENTIFIERS Computer Software

ABSTRACT

The computer management system described, which administers tests and provides feedback to examinees, as well as progress summaries to instructional personnel, has been implemented at Florida State University. Located in the Assessment Resource Center (ARC), it has been used to manage the instruction of several thousand students enrolled in courses offered by 15 academic departments. Because of its relatively low cost, this system can be implemented on a large scale by many educational institutions; however, if such systems are to be effective, they must be designed into compatible and valid measurement and instructional systems. This paper describes the system, discusses relative costs for hardware and personnel and addresses some of the measurement and instructional implications of using the system. (CMV)

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COST-EFFECTIVE COMPUTER MANAGEMENT OF INSTRUCTION

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

Presented at the Annual Meeting of

American Educational Research Association

San Francisco, California

April, 1979

IR007383

Cost-Effective Computer Management of Instruction

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Thorndike (1971) indicated that the most dramatic changes in educational measurement that have occurred during the past twenty years have been those which have stemmed from technological progress, especially the development of the optical scanner and computer. This phenomenal advancement in electronic technologies has obviously progressed at an accelerated rate during subsequent years with no sign of abatement in the near future. Consequently, in many areas, it is possible to use the computer to administer tests, provide immediate and prescriptive feedback to examinees, present progress summaries to instructional personnel, and control subsequent testing of students basing management decisions on previous performances with diagnostic examinations. Even with other educational costs going up, the cost of electronic computing has decreased.

Nevertheless, computer systems with time-sharing capability represent a significant investment for educational institutions. Although most institutions and schools systems at a minimum lease computer time on such a system, much of the computing power allocated to "education" is consumed by scheduling of courses, managing the payroll, and other inventory control functions that are cost-effectively processed by computer. Widespread use of a computer for managing or delivering instruction is the exception to the rule at most educational institutions.

The present paper describes a variation of computer managed instruction which, because of its relatively low cost, can be implemented on a large scale by many educational institutions. The physical location at which this system is implemented is referred to as the Assessment Resource Center (ARC). Currently, the ARC is being used by Florida State University to manage the instruction of several thousand students enrolled in courses offered by 15 academic departments. This paper will describe the system, discuss its relative financial costs in terms of hardware and personnel requirements, and also address some measurement and instructional implications of using the system.

Description of the System

The computer management system is what Mitzel (1974) refers to as a "Level III" CMI application in that it incorporates a real time interactive interface between the learner and the computer as well as diagnostic-prescriptive logic keyed to the students' responses to the material managed by the computer. Unlike other Level III applications, this system does not utilize individual computer terminals for each student. Instead, four terminals including a small online optical scanner are located at the testing site and shared by a large number of students. These terminals are operated by a student assistant serving as a proctor.

Operation of the System

Each student comes to the ARC after completing a unit of instruction. The student then fills in a machine scannible form indicating who he or she is, and the identity of the unit of instruction on which the student is to be examined. The proctor verifies the students' identity and inputs the form into the optical scanner, which in turn transmits the information provided by the student to a remote computer. The computer accesses its files to determine the appropriateness of the student's request, and identifies to the proctor the appropriate set of test materials to be provided the student. Since the computer contains data pertaining to each student's performance on current and previous units of instruction, it is able to make decisions as to if prerequisite units of instruction have been sufficiently mastered, and whether the student is maintaining an adequate rate of learning.

Upon receiving the test materials, the student takes an assigned seat within the ARC. Test materials are used by the student away from a computer terminal, and student responses are recorded on an answer form. After completing the test, the student returns the test materials and answer form to the proctor. The answer form is read by the optical scanner which relays the student's responses to the computer. The computer updates its files, and controls the printing of a prescriptive report which is handed to the student moments after completing the test. As directed by the feedback, the student will remediate any difficulties which were diagnosed by the test, and then return to the testing site within a predetermined amount of time for reassessment of these competencies.

Because the testing process is controlled by a computer, a large number of students from different courses, and at varying stages within the respective courses, can be simultaneously taking tests in the ARC. Whereas a proctor distributes materials and monitors the testing environment, the management capabilities of the computer permits a small number of personnel to distribute and process test materials that meet the individual needs of a large number of students.

Use of Nonprint Test Stimuli

The assessment resource center concept also allows the inclusion of testing procedures that use nonprint stimuli. The use of media aids in instruction is well accepted. For example, most would agree that the concept of syncopation is more effectively taught using an audible stimulus. Similar examples exist through music theory, as well as art, interior design, the various social and physical sciences and so on.

The point being made here is not that the use of nonprint stimuli is new to the area of assessing student achievement. Many disciplines presently incorporate audio and video tapes, slides, and other media in their evaluation of student performance. Medical schools in particular have placed considerable emphasis on mediated testing. The point being

made is that the assessment resource center concept allows the utilization of nonprint stimuli as well as the more traditional printed tests. Because the ARC administers tests away from computer terminals, a variety of test stimuli such as graphical, pictorial, audio and motion can be used in addition to the printed stimuli provided by most computer terminals. And the provision of immediate prescriptive feedback to students and other computer management qualities can still be provided.

Description of the Computer Software

The computer software that drives and otherwise services the ARC system consists of the "central software" and the "auxiliary software." The central software is used each time a student takes a test, and is responsible for determining if a student has met conditions prerequisite to taking a test, assigning appropriate test materials to each student, scoring each test, providing prescriptive feedback to the student, and updating disc files relative to each student's progress. In order to handle a high volume of students without being obtrusive to other computer functions, the central computer software actually consists of four separate and relatively small programs which communicate with each other through common disc files. The auxiliary software consists of several independently functioning computer programs that facilitate the use of the central software: Two registration programs are used for batch and individually registering students into the system; a series of student management programs provide instructors with current summaries of student progress, estimated final grades, and analysis of test items; several system management programs have been developed which tabulate usage and operational costs of the system, as well as forecast its usage based upon past utilization.

Central ARC Software. The central computer software associated with the ARC is responsible for determining if students have met conditions prerequisite to taking a test, assigning the appropriate test materials to each individual, scoring tests at the completion and providing prescriptive feedback to examinees, and updating appropriate disc files containing student progress and Center usage data. The Figure diagrams the functional relationship between the four main programs that constitute the central software. These programs are executed twice for each student use of the ARC; the first execution occurs when a student enters the Center, and the second when a student completes the test. The single connecting lines in the Figure represent the first execution, whereas the double lines represent the second execution.

When a student enters the ARC, he or she fills in a paper form listing a student identification number, and the code to the unit of instruction to be examined. Information from this form is scanned by an optical reader which inputs the information to the Input and Form Assignment Program. This program in turn obtains information from the indicated data files. Student A records contain information about the current status on all instructional units for each student in a

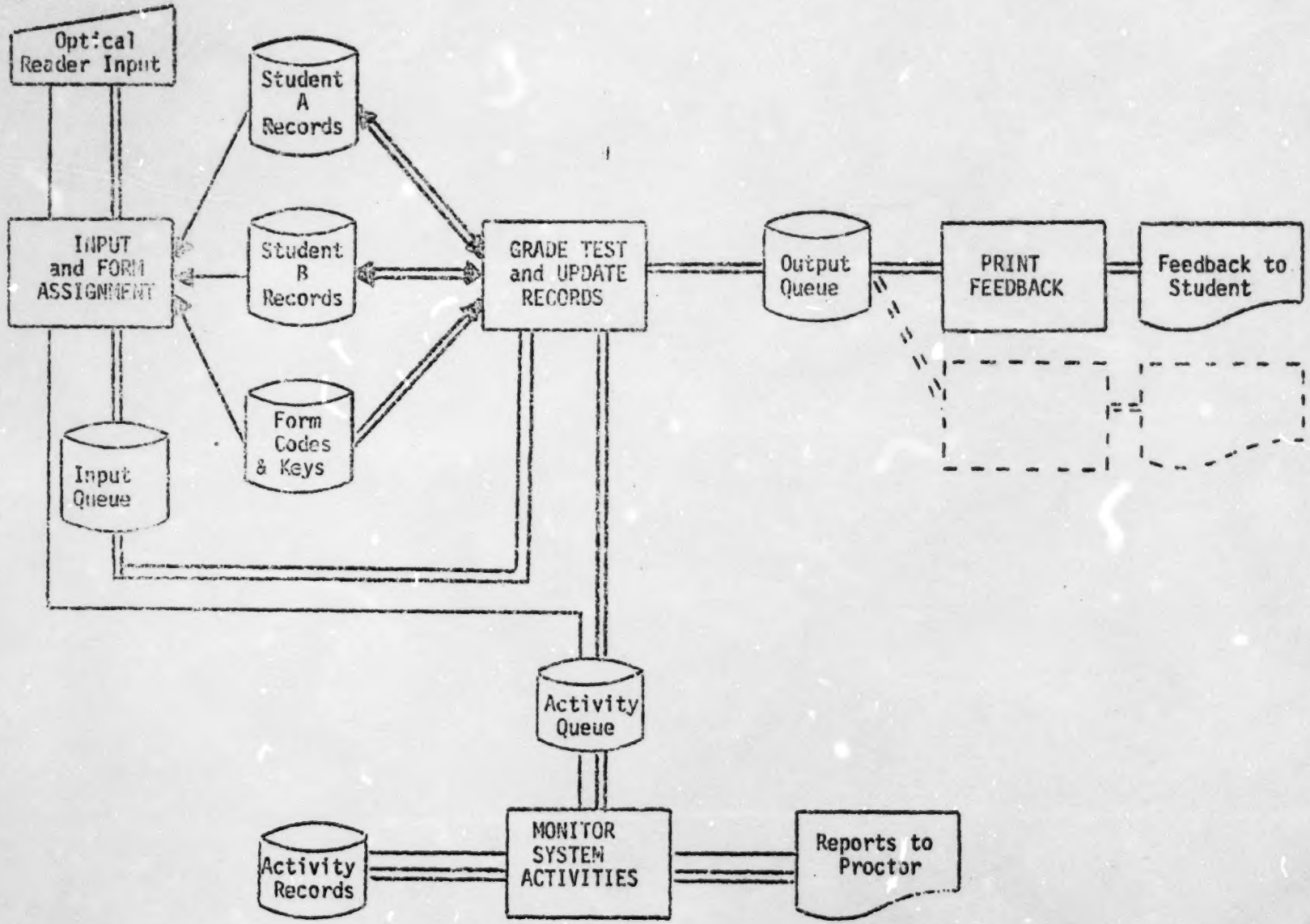

Figure. Functional relationship among ARC central software programs.

given course; Student B Records indicate what test materials were used by each student to get to the current status and the dates and times which these materials were used. The information contained in these files is specific to a particular course, and an overlay is used by both the Input and Form Assignment Program (and later by the Grading and Record Update Program) to make the varying files compatible to a common program. The Form Codes and Keys file is a read only file and contains the answer keys, item weights, and corresponding identification codes for each test available to a particular course. Copies of these three disc files are established for each course using the ARC.

When the Input and Form Assignment Program determines that a student has requested a test within an instructional unit, the three Data Files are used to determine whether the student has completed instructional units prerequisite to the present request, is making the request within a specified time period (i.e., student pacing), and whether the student has been retested too frequently without making contact with the instructor for special assistance. If all preconditions to testing have been met, a specific set of test materials are assigned to the student. Decisions made by this initial contact with the Input and Form Assignment Program are recorded on the communications file labeled Activity Queue which serves as the input to the Subsystem Monitoring Program. This latter program communicates to the ARC proctor the specific set of test materials to be assigned to the student, or describes the nature of the difficulty if conditions prerequisite to the student's request have not been met. Communication to the proctor is via an onsite terminal. This communication, and all other activities records of the Input and Form Assignment Program and the Grading and Updating Programs are recorded for future reference or evaluation by the Subsystem Monitoring Program.

The Activity Queue is one of three sets of files used to transfer information between the four main programs. The Figure somewhat simplifies the actual communication process. Each of the queues are direct access files. If a file is busy due to its simultaneous use by one of the other programs, the program being locked out of the busy file will access a secondary file. This approach to communicating between programs allows each program to process a maximum number of students without interference from the simultaneous activities of the other subsystem programs.

After a student completes the test exercises, the original paper form which now contains the student's responses to the test is reread by the optical reader. The Input and Form Assignment Program, determining that the paper form is ready for grading in contrast to representing a request for form assignments, outputs the student's responses to the Input Queue process.

The Grading and Updating Program receives this input, and first references the three Data Files to verify that the student's original request and indication of subsequent form assigned have not been altered. The program then grades the student's responses and makes decision regarding the student's new status on the just examined unit. The

program determines the appropriate format and contents of the prescriptive feedback to be provided the student, outputting this information to the Output Queue. Student A and B records are immediately updated to reflect these completed activities. Through use of program overlays, the decision rules used for determining student status and for determining format of the prescriptive feedback can vary between courses and between units within courses.

The Feedback Processing Program controls the outputting of the student's feedback to a hardcopy terminal. When more than one testing site is used, this program delivers feedback to the appropriate site.

Dividing the activities of the central computerized management subsystem across several programs has three distinct advantages. First, each program requires (on a CDC Cyber 74 computer) relatively small core, ranging from 15K positions octal for the Feedback Processing Program to 32K positions octal for the Grading and Updating Program. Second, all of the programs can function simultaneously thus increasing the throughput of students. Third, sectioning of activities allows the removal of bottlenecks anywhere within the system by loading two or more copies of a particular program into the computer. This option is illustrated in the Figure for the Feedback Processing Program which allows two or more terminals to be utilized for printing feedback if this were required by heavy usage. This option could also be used by any of the other programs; for example, two optical readers could be put into service at one or more separate sites. The three advantages describe how dividing the subsystem into four modules allows the maximization of efficiency provided by a timesharing computer. This maximization is further strengthened by a computer system option that "puts to sleep" any program that is not being utilized at a point in time.

Auxiliary ARC Software. Several independently functioning programs have been developed that utilize the Data Files described above to support the operation of the Assessment Resource Center. These programs are grouped into the area of student registration, student management, and center management.

Student registration programs: Two programs are used in registering students for use of the ARC. Each of these programs creates alpha sorted files that include student name, identification number, and student option selection. Student options include any decision which is under the control of students such as publicly posting (for reference) current status of each student by identification number. Information inputted through the registration programs is recorded on paper forms and usually batch read by the optical reader. The first program batch registers students. (The registration programs interactively register late enrolling or small groups of students, and allows the ARC staff to correct records of previously registered students.)

Student management programs: The instructor of a course may at any time request a status summary of students. This summary is designed specifically for each course and contains information such as individual and group status on each objective, number of retests required, estimated

final grades, and item analyses. These summaries are up to date since the programs access the same files as used by the central software. At the beginning of each day master summary status report, by identification number instead of name, is outputted for all courses using the ARC for students wishing to have this information available in this manner.

Center management programs: Several programs have been developed which tabulate the usage and cost of operation of the ARC. These programs are useful for evaluating the cost-efficiency and cost-effectiveness of the Assessment Resource Center. Of particular interest is a program that predicts the type of usage the ARC will receive across an upcoming academic quarter, and allows the ARC staff to interactively increase or otherwise alter the usage of the ARC and make immediate projections of the consequences of these alterations to usage of the ARC.

Computer Costs of the ARC System

The purpose of the Assessment Resource Center concept has been to deliver the benefits of computer managed instruction at a cost sufficiently low to allow widespread use of such a system. Relative costs of the ARC system are discussed in terms of price of computer peripherals, load placed on the central computer, personnel required to adapt the software to additional courseware, and personnel required to operate the system.

Computer Peripherals

The ARC was designed to be cost effective relative to typical Level III CMI systems. As indicated earlier, such a system is characterized by a real time interactive interface between the learner and the computer. Other Level III systems achieve this interface by assigning each examinee to a computer terminal. Even though a single terminal can service a number of students each day, the quantity of terminals required to service a large number of students will result in a substantial investment.

The classic Level III CMI system prescribes instruction that occurs away from the computer terminal. The approach used by the ARC retains the immediate prescriptive feedback provided each student at the completion of a test, but, as with the instructional component, removes the actual administration of test items from the computer terminal. Removal of testing from the terminal limits the provision of feedback after each response to individual items and also the presentation of subsequent items based on an examinee's response to previous items such as required by sequential testing; neither of these qualities are appropriate for most instructor constructed course examinations. Benefits obtained by removing test administration from the terminal are fewer restrictions on the item format, reduced frustration in the event of computer failure, and reduced cost for purchase and maintenance of computer peripherals.

Because the ARC system uses a set of four computer terminals to service a large group of students, the cost of peripherals becomes a step function that increments in cost each time an additional set of four terminals becomes saturated by a sufficiently large volume of students. In the classical Level III CMI system, the number of terminals required is proportional to the number of testing hours utilized by a testing site (one student requiring 60 minutes to complete a test equals one testing hour). Payne and Oosterhof (1978) estimated that the cost of computer terminals required by the ARC system equals that of classical Level III CMI systems when the testing site logs an average of approximately seven testing hours per day. However, when operating at capacity (increments of approximately 60 testing hours), the relative cost of terminals for the ARC system reduces to 10 to 15 percent that of the classical system.

Load Placed on the Computer

The ARC system places considerably less of a load on a computer's mainframe than a classical Level III CMI system. The differential in load is dependent upon the configuration of a particular computer, however the difference is easily apparent when discussed in the general case. Merrill (1974) described a Level III system that was operational at Florida State University at that time. Several subject areas made use of this system, with the computer memory requirements varying from approximately 40 to 70K octal for driving programs associated with the systems adaptation to the various courses. One copy of a version of the CMI program would be active for each terminal being used to administer a test. If 60 students were taking tests at a given point in time, 60 programs, each requiring 40 to 70K of memory, were active within the computer. In contrast, the same 60 individuals would share four programs requiring from 15 to 32K octal in memory when utilizing an ARC type system.

An ARC type system also requires fewer accesses to disc storage per test administration, whereas a Level III system requires a minimum of one access per test item presented, in addition to the accesses required to read and update student record files. (A side benefit of the fewer accesses is that in the event a computer program is placed in a "wait" mode while executing the result will be a minute delay in receiving test materials or prescriptive feedback for an ARC user in contrast to a minute delay in being presented the next item for a Level III system user.)

Developmental Personnel Requirements

There is no significant difference between the ARC and Level III CMI systems with regard to personnel time required to adapt courseware to the computerized system or to adjust computer software for inclusion of the additional courseware. Both approaches actually require an insignificant amount of computer software development time for including additional courses if the software is designed to be content free, i.e.,

does not build into the computer program material that is specific to a particular set of courses. Some CMI systems incorporate substantial amounts of materials into the actual programs that are relevant to only one course such as feedback information that informs the examinee on which page within a particular text information to be reviewed will be found. There is nothing inappropriate about explicit feedback, however this content specific information should be inserted into software packages where it is readily changed such as in data files, or should be provided separate from computer generated outputs such as through handouts. The ARC system, as with a number of Level III systems, is content-free in its software construction.

From moderate to substantial personnel time is required to develop or modify courseware so that it will effectively take advantage of the instructional qualities of computer management. A discussion of these efforts is beyond the scope of the present discussion, but is addressed in the conclusion of this paper.

Operational Personnel Requirements

Level III and ARC computer management procedures both require the same number of personnel to operate the respective systems when used to administer course examinations. Both approaches require that staff verify student identities and transmit this verification into the computer in some form. Both require available support in the event operational clarifications are required, or in the event there is a computer or other system failure.

A greater disparity in cost occurs when alternate modes in addition to computer management are compared. Oosterhof (1979) compared four methods of administering and responding to course examinations. Incorporating all labor associated with administering and processing tests including faculty and clerical time, the ARC-type approach was used as a standard with an index of 1.00. Using average compensations for faculty, graduate, and undergraduate student assistants, and relevant classifications of clerks, a fictitious course enrolling 500 students within 10 sections was used for comparing costs of alternative approaches. An index of 1.06 (i.e., a 6% increase in cost) was obtained when exams were administered in class, machine scored at a remote site, and test scores returned to students again in class. An index of 3.29 was obtained when the course staff tried to provide some of the same services of computer management by providing basic diagnostic feedback to each student regarding performance on an initial test, and then providing for a retest after students had an opportunity to remediate difficulties. An index of 2.56 to 5.98 was obtained when a comparison was made to the test administration/reporting aspects of a Keller Plan approach (which has more recently been referred to as the Personalized System of Instruction (PSI); variability in the index was the result of using alternate configurations of student assistants serving as proctors.

The respective indexes might be challenged on the basis that faculty are not paid more or less as a function of administering fewer or additional tests. Similarly, PSI approaches typically use students who pay for and receive credit for their experience instead of being paid for their service. However, economists would argue that quality of productivity is altered as a consequence of this "free help." The value or utility of the altered quality would have to be determined with respect to the changed behavior, be it changes in ability to conduct research, review literature, revise course material, write grant proposals, or become involved with recreational activities. In terms of PSI functions, studies have shown that students can gain from the proctoring experience, but that this gain is offset at least somewhat by additional training and supervising responsibilities placed on the course instructor.

Summary and Conclusions

The Assessment Resource Center system was designed to provide a cost-effective alternative to the classical Level III system. Within this comparative setting, the ARC concept appears to have accomplished that goal with respect to cost of computer peripherals and load placed on a computer mainframe. In terms of cost associated with operational personnel, it has been argued that, as with Level III CMI systems, the ARC approach is competitive to other forms of administering and processing tests.

A concluding issue is whether the absolute cost of the ARC or similar systems is sufficiently low to justify its widespread adaptation. At best, the cost of the ARC can be financed by the cost it alleviates. At worst, it represents an additional cost while offering no worthwhile service. A significant portion of the response to these questions is found by researching a second but parallel question: Is the instructional worth of this system sufficiently high?

The ARC and similar systems must be designed into compatible and valid measurement and instructional systems. Unless valid tests are used, and appropriate instructional and remedial experiences are provided students, the ARC only represents an additional cost to the institution. At Florida State University, the ARC has been limited to use by courses where instructors and departments are willing to address these measurement and instructional design issues. Evaluation data supports the position that insistence on addressing these issues results in a beneficial service. For example, among a sample consisting of 36 instructors using the ARC, 67% indicated the quality of their tests improved, 75% indicated that the ARC procedures improved student learning of course material, and 93% supported the continuation of the ARC system. The evidence is preliminary and further replication is required under varying conditions, but there is reason to believe that the Assessment Resource Center, and computer management systems like it, play a valuable role in the education process.

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